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# A NEW CLOUD DETECTION ALGORITHM FOR NOAA AVHRR IMAGERY

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## Abstract

*For environmental monitoring of Earth's surface, one of the major problems is a detection of cloud-contaminated pixels. This paper describes a new automatic cloud detection algorithm. The method combines threshold method using local area parameter and clustering procedure. It has been successfully tested using AVHRR data of the Far East region where contains a mixture of land and ocean. Also, using N-Land database results obtained with this scheme compared favorably with those obtained with Saunders and Kriebel algorithm, which is one of the standard cloud detection procedures.*

## I. INTRODUCTION

Remote sensing of the Earth's surface by satellites is first of all important because of its global coverage. In recent years as an offer of environmental information which is closely concerned with our lives, importance of global environmental observation using satellite remote sensing is growing increasingly.

Data from the Advanced Very High Resolution Radiometer(AVHRR) on board the NOAA polar orbiter series of meteorological satellites are being used by a large number of researchers, due to its spatial coverage and spectral resolution. Most parts of the world are covered at least twice daily by one satellite, which leads to the possibility of four times per day for two-satellite system. In addition AVHRR sensor has a minimum pixel size at nadir of 1.1km and can observe the surface at five wavelengths.

To observe sea or land surface, one of the major problems is the elimination of cloud-contaminated pixels. Cloud-contaminated pixels affect the remotely sensed value of the surface reflectance and the results such as vegetation index, surface albedo, field classification etc. For this reason, to identify cloud-free pixels is a critical step in the analysis of satellite data.

There has been much interest in developing algorithms for detection clouds in remotely sensed data. Recently, multi-spectral statistical approaches are reported in literature based on threshold[1][2], 2- or 3-dimensional histogram[3] and pattern recognition method[4] etc. However the majority of the algorithms developed require different well-defined threshold or training data set, if

observation region is changed. And there are several classification problems when we apply these methods to the Far East area. Thus, little is known about automatic cloud detection algorithm for NOAA AVHRR images in the Far East region.

This paper develops a new automatic cloud detection scheme for NOAA AVHRR images using threshold method and clustering method.

## II. NOAA AVHRR DATA

The AVHRR on board NOAA is a cross-track scanning system and observes the surface at five wavelengths, as shown in Table 1. The instantaneous field of view(IFOV) of each channel is approximately 1.4milliradians leading to a resolution at the satellite subpoint of 1.1km for a nominal altitude of 833km. The scanning rate of the AVHRR is 360 scans per minute. A total of 2048 samples will be obtained per channel per earth scan, which will span an angle of  $\pm 55.4^\circ$  from the nadir.

## III. CLOUD DETECTION ALGORITHM

A new automatic cloud detection algorithm combines the threshold method and the clustering procedure. At first, the threshold method separates the image into three regions, which are clear region, cloud region and region that contains a mixture of clear and cloud pixels, using the threshold method. In clear region, we collect pixels that must be a clear pixel clearly. Also, in cloud region, we collect pixels that must be a cloud-contaminated pixel clearly. All the rest of pixels are collected as mixture region. Then each region is segmented using clustering procedure. Finally, each cluster of mixture region contains clear and cloud pixels are classified using minimum distance method.

Table 1. Characteristics of NOAA/AVHRR

Channel	Range( $\mu\text{m}$ )	Notes
1	0.58 - 0.68	Visible. Surface feature
2	0.725 - 1.10	Near-infrared. Water and vegetation
3	3.55 - 3.93	Thermal. Fires, volcanoes etc.
4	10.3 - 11.3	Thermal. Surface temperature, cloud
5	11.5 - 12.5	Thermal. Surface temperature, cloud

### The Threshold Method

The threshold method[5] to make a clear or cloud region, combines two tests, which is visible test and infrared test. Each test to detect pixels that must be a cloud pixel is described below.

All pixels that are assumed to be cloudy in either visible test or infrared test, are identified as cloud-contaminated pixels. As clouds generally reflect more visible light than most types of land and water surfaces, except snow and ice, we can set a threshold value  $Thr$  such that visible reflectance,  $Ch$  higher than  $Thr$  is considered as a cloud-contaminated pixel. Fig.1 shows the relationship between sun elevation and the reflectance. Sunlight, radiated from the sun is reflected at the point of observation and reach AVHRR sensors. For sun elevation,  $\theta$ , the reflectance,  $I_r$  reached AVHRR sensors is computed from relationship

$$I_r = \alpha \sin \theta + \beta \quad (1)$$

where  $\alpha$  is the correction constant and  $\beta$  is the atmospheric factor. From the data obtained at different sun elevation, we can find optimal constants,  $\alpha$  and  $\beta$  for each different regions. Therefore the visible or near-infrared threshold, detecting the cloud pixels, is given by

$$Th_r = \alpha \sin \theta + \beta \quad (2)$$

The basic principle in infrared test is to detect pixel that have an infrared radiative temperature lower than a pre-determined threshold as a cloud-contaminated pixel. First, a monthly minimum brightness temperatures over clear land(sea),  $Tmin1(Tmin2)$  are determined from 2 years AVHRR imagery(1996,1997). Our infrared test in channel-4 is based on the assumption that, the values of brightness temperature in an ensemble of pixels with value higher than  $Tmin1(Tmin2)$  are distributed normally. Then infrared thresholds,  $Thland$  and  $Thsea$  are defined

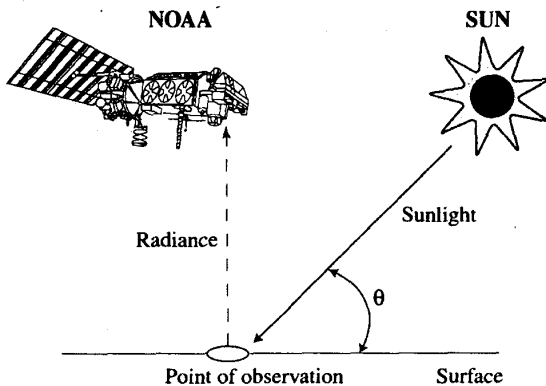


Fig.1. Relation of sun elevation and visible reflectance

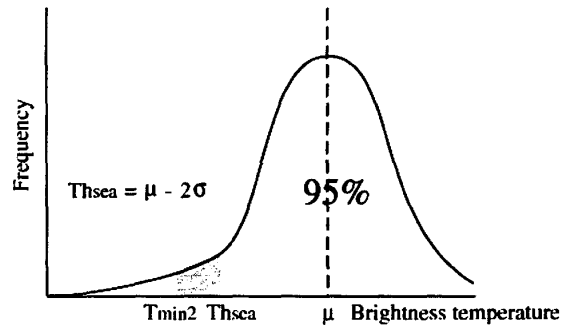


Fig.2. Determination of infrared threshold over sea on histogram of channel-4

as the values that include 95% of that distribution, as shown in Fig.2.

### The Clustering Method

After threshold method, each region is segmented using clustering procedure. A schematic flowchart of clustering algorithm is shown in Fig.3 and summarized as follows:

- Initialization:** Determine initial cluster centers of each region.
- Relabeling:** Assign each vector in the image to one of the clusters using minimum distance method. In this study, we use the Mahalanobis distance.

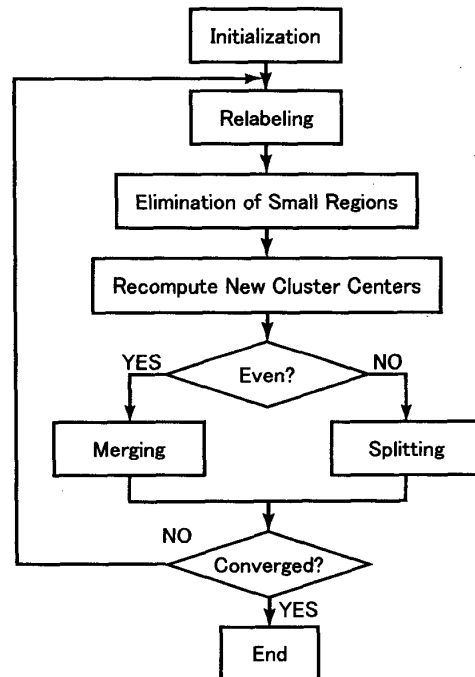


Fig.3. Overview of clustering procedure

- c. *Elimination of Small Regions*: combine each small region with the most similar region adjacent to it
- d. *Recompute New Cluster Centers*: This is performed for the new clusters that result from steps b-d.
- e. *Check the number of iteration*: if the number of iteration is even, go to step f, otherwise step e.
- e. *Splitting*: Check all clusters and split them if within-cluster variance is larger than pre-determined variance.
- f. *Merging*: Check all possible groups of two clusters and combine them if between-cluster distance of them is less than pre-determined distance.
- g. *Convergence Checking*: Beginning with step b, continue the procedure until converge.

Finally, each cluster of mixture region contains clear and cloud pixels are classified using minimum distance method.

#### IV. RESULTS

The cloud detection scheme was tested using N-Land database[6]. N-Land image consists of 198 cells with 32×32-pixel and its location is Tohoku region in Japan, situated north of Tokyo. Each pixel in the N-Land database was flagged manually by experts as land, ocean and cloud. In this study, 5 scenes in 1989 of N-Land database are selected and applied to the cloud detection scheme and Saunders and Kriebel's cloud detection algorithm.

The result of the comparison are shown in Table 2. The percentages are of the number of pixels identified correctly as cloudy and clear by each algorithm out of the number of pixels flagged as cloudy and clear by experts. As can be seen from Table 2, we generally found that the proposed algorithm has better performance than Saunders and Kriebel's algorithm.

An example of N-Land database applied to comparison is shown in Fig.4. Fig.4(a) shows channel-2 image for 12 August 1989 at 03 45 GMT and Fig.4(b) shows the cloud mask with white pixels produced manually by expert. The results of Saunders and Kriebel's algorithm and the proposed cloud detection scheme is

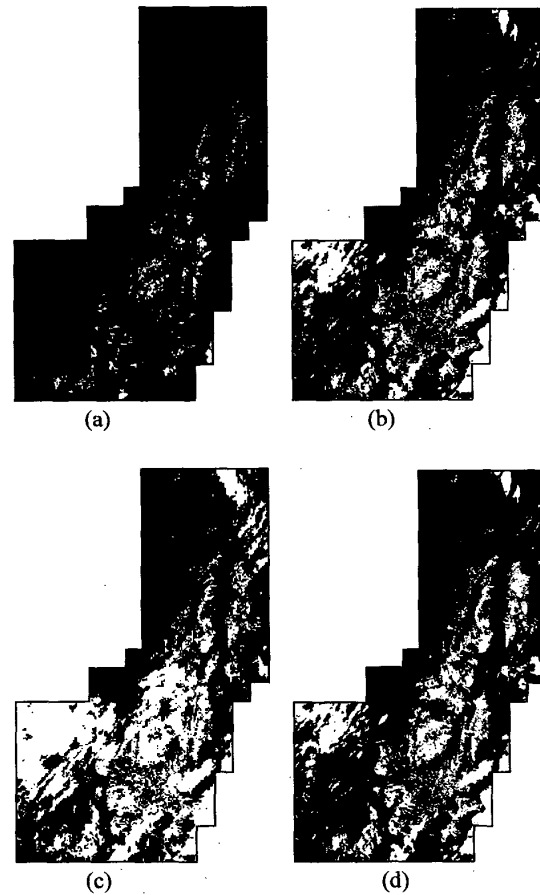


Fig.4. An example of N-Land database channel-2 image(a) and the cloud mask with white pixels produced by an expert manually(b), Saunders and Kriebel daytime procedure(c), and new cloud detection scheme(d)

shown in Fig.4(c) and (d), respectively.

Also, the cloud detection scheme was tested using NOAA AVHRR imagery over the Far East region. These data were obtained from the satellite receiving station at Tohoku University in Japan. Data with 1024×1024-pixel was derived for two continental and one oceanic region scattered over the Far East. They are a region of the Korean peninsula(approximately 39°N 128°E), parts of the China(approximately 31°N 121°E) and parts of Pacific ocean(approximately 28°N 145°E). By inspection, we confirmed that there is no undetected cloud pixels in the result.

#### V. CONCLUSION

A new automated scheme to detect cloud-contaminated pixel of AVHRR imagery has been developed. Results obtained with this scheme compared favorably with those obtained with Saunders and Kriebel's

Table 2. The comparison of the cloud detection scheme using N-Land database listed

N-Land Image	The proposed algorithm	Saunders and Kriebel's algorithm
13 June 1989	91.4%	89.8%
12 August 1989	91.7%	80.7%
19 August 1989	93.8%	90.9%
22 August 1989	88.7%	89.2%
10 October 1989	91.2%	85.6%

algorithm that is one of the standard cloud detection procedure. Also it has been successfully tested using AVHRR data of the Far East region.

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#### **REFERENCES**

- [1] R. W. Saunders and K. T. Kriebel, "An improved method for detecting clear sky and cloudy radiances from AVHRR data," *Int. J. Remote Sens.* vol.9, pp.123-150, 1988.
- [2] T. F. Eck and V. L. Kalb, "Cloud-screening for Africa using a geographically and seasonally variable infrared threshold," *Int. J. Remote Sens.* vol.12, pp.1205-1221, 1991.
- [3] J. Kudoh and S. Noguchi, "Identification of fog with NOAA AVHRR images," *IEEE Trans. Geosci. Remote Sensing*, vol.29, pp.704-709, 1991.
- [4] J. J. Simpson and J. I. Gobat, "Improved cloud detection for daytime AVHRR scenes over land," *Remote Sens. Environ.* vol.55, pp.21-49, 1996.
- [5] W.H. Lee, J. Kudoh and S. Makino, "Cloud elimination method for temporal analysis in the Far East Region with NOAA AVHRR," *IGARSS'99*, 1999
- [6] H. Kawamura and Y. Edamatsu, "N-Land database for researches of the Japanese land and coastal area with complicated geographical features," *IGARSS'93*, pp.1941-1943, 1993.